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SAS-A SPACECRAFT MAGNETIC TESTS

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GSFC — GODDARD SPACE FLIGHT CENTER
GREENBELT, MARYLAND

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Test and Evaluation Division
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GODDARD SPACE FLIGHT CENTER
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SAS-A SPACECRAFT MAGNETIC TESTS

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PROJECT STATUS

This is the final report of the magnetic testing of SAS-A as performed at the Magnetic Test Site, GSFC. After completion of all tests the SAS-A was launched on December 12, 1970 from the San Marco platform into an approximately 300 nautical mile circular equatorial orbit.

AUTHORIZATION

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SAS-A SPACECRAFT MAGNETIC TESTS

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SUMMARY

The SAS-A spacecraft was tested in the GSFC Spacecraft Magnetic Test Facility (SMTF). An initial series of tests took place July 20-28, 1970 and a final series October 23 and 24, 1970.

In the initial series of tests, the "as received" permanent magnetic moment components were found to be:

$$M_x = -258 \text{ Milliampere-Meters}^2$$

$$M_y = -47 \text{ Milliampere-Meters}^2$$

$$M_z = +244 \text{ Milliampere-Meters}^2$$

After permanent magnet compensation, the values were reduced to:

$$M_x = +59 \text{ Milliampere-Meters}^2$$

$$M_y = -47 \text{ Milliampere-Meters}^2$$

$$M_z = -49 \text{ Milliampere-Meters}^2$$

The Z coil dipole moment was adequate in the high gain mode (4.9×10^4 milliampere-meters^2), but was only about half strength (0.46×10^4 milliampere-meters^2) in the low gain mode.

Residual moments due to Z coil operation were minor and were corrected by the onboard demagnetizer.

The X and Y chargeable trim magnets produced changes in moment of approximately ± 200 milliampere-meters^2. The Z chargeable trim magnet produced changes of ± 900 milliampere-meters^2.

Spurious dipoles due to operation of onboard subsystems were negligible, except for the nutation damper solenoid. This produced a moment change along its axis of 365 milliampere-meters^2 when energized.

The torquemeter technique proposed for measurement of induced dipoles was not successful.

Magnetometer alignment, bias check, and calibration were successfully performed.

Torques produced by the spin-despin system were measured both statically and with a rotating field. The measured values confirmed the design both in magnitude and direction.

In the final series of tests, the perm moment components after recompensation with permanent magnets were

$$M_x = 12 \text{ Milliampere-Meters}^2$$

$$M_y = 0$$

$$M_z = 0$$

Spurious moments were of the same order as in the initial test except that the tape recorder in the playback mode produced a moment along the X axis too large to be nulled out with the chargeable trim magnet. This recorder had been replaced subsequent to the initial test.

The attitude (Z) coil produced a moment of 42,000 to 47,000 milliampere-meters^2 in the high gain mode but nothing in the low gain mode. After the magnetic tests were completed, it was discovered that insulation had been worn off by mechanical abrasion. This was reported to have been corrected.

No spin system torque measurements were made during the final tests. However, torques were calculated by analog computer, using as inputs signals proportional to the components of the rotating field and also signals proportional to the currents present in the X and Y satellite spin system coils. Computations were made over a range of frequencies from the lowest possible (approximately 0.3 RPM) to 10 RPM with amplitudes ranging from 10,000 to 35,000 nanoteslas. The torques were of the anticipated magnitude at the lower frequencies but read somewhat higher (about 15%) at the maximum frequency. This appeared to be due to a frequency sensitivity within the analog computer.

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SAS-A SPACECRAFT MAGNETIC TESTS

INTRODUCTION

The SAS-A spacecraft is designed to detect X-ray sources both galactic and extra-galactic. It was boosted into an approximately 300 nautical mile equatorial orbit by a 4 stage Scout vehicle, from the San Marco Platform, at Kenya, Africa.

The spacecraft spins at a nominal rate of 0.0087 rad/s (1/12 RPM) with its spin axis capable of being maneuvered so as to scan or to point to regions of interest. This is accomplished by an attitude and spin control system which utilizes the following principal components:

A stabilizing rotor to provide adequate angular momentum about the spin axis despite the slow rotational rate of the spacecraft.

A Z axis torque coil which, when energized, develops a magnetic moment to interact with the ambient geomagnetic field to precess the spin axis.

X and Y axis torque coils which, when energized, develop magnetic moments to control the rate of spin.

A nutation damper to dissipate energy associated with angular velocity components normal to the Z axis and thereby damp out wobble.

A chargeable trim magnet system controlled by ground command to produce small permanent magnet dipoles to compensate for extraneous on-board dipoles.

A 3 axis vector magnetometer for controlling the current flow to the spin and attitude coils and, in conjunction with a system of solar attitude detectors, for attitude determination.

An on-board demagnetization capability for the purpose of eliminating extraneous residual dipoles.

PURPOSE

The objectives of these tests were as follows:

Alignment, compensation, calibration and bias determination for the spacecraft three-axis vector magnetometer.

Determination of permanent, induced and stray magnetic moments of the spacecraft and compensation of permanent magnetic moments by permanent magnets.

Evaluation of the spin and attitude control system.

TEST DESCRIPTION

Set-up

The tests were conducted in the GSFC Spacecraft Magnetic Test Facility. This facility utilizes a 12.8 meter (42 foot) diameter Braunbek coil system to produce a controlled magnetic field of high uniformity over a large central volume. The facility is described in Appendix A.

The SAS-A spacecraft was mounted on the Mark VI Torquemeter in the center of the coil system. During the dipole moment measurements, the spacecraft was mounted with its Z axis horizontal, using a special roll fixture; the solar paddles were not in place. Protection against air currents was provided by a clear plastic curtain approximately 6 meters in diameter and, in addition, a rigid cylindrical enclosure of masonite, approximately 2-1/2 meters in diameter by 2 meters high. This set-up is shown in Figure 1.

For all other phases of the tests, the spacecraft was mounted vertically on the torquemeter with the solar paddles in place, as shown in Figure 2.

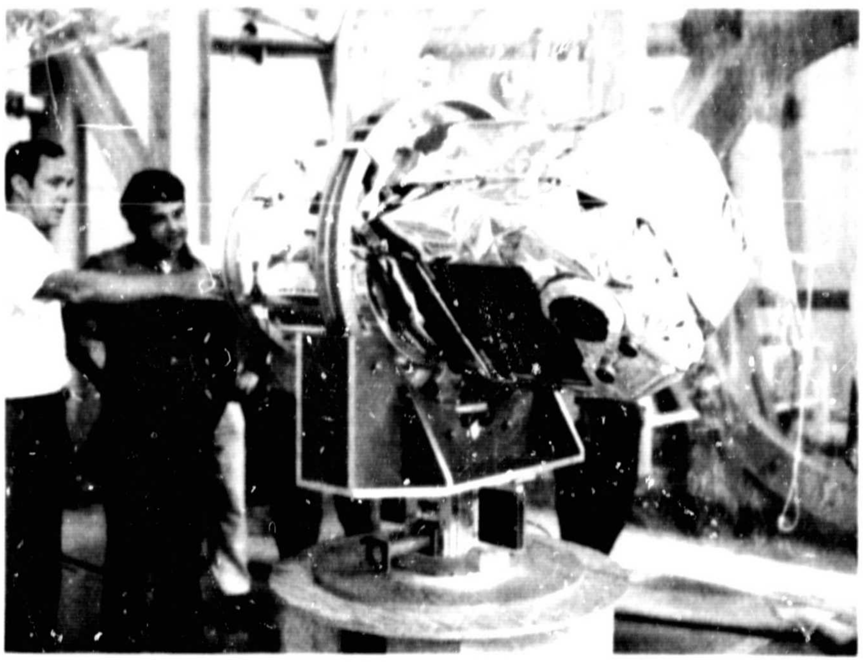

Figure 1. SAS-A Test Configuration for Dipole Measurements

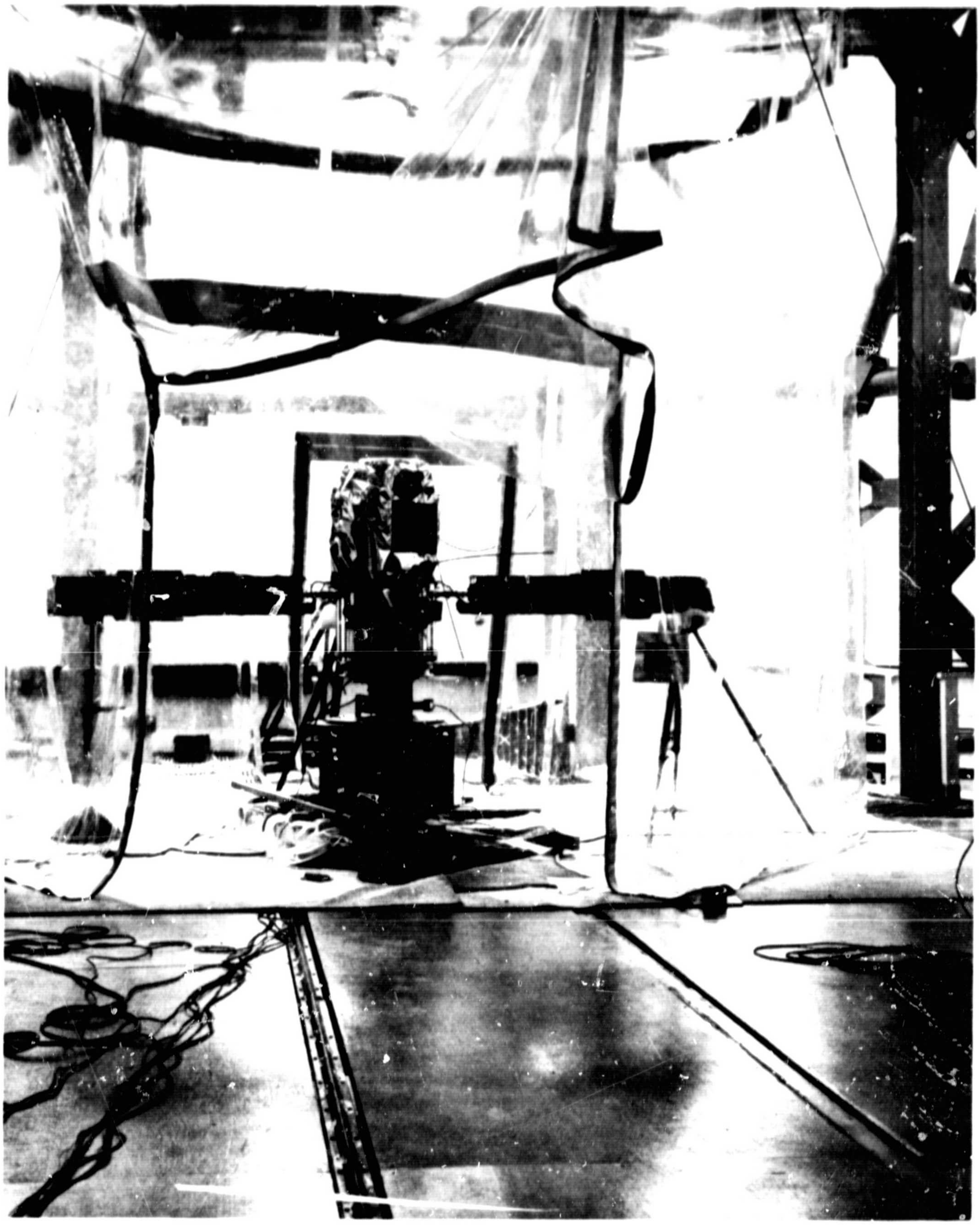

Figure 2. SAS-A Test Configuration for Magnetometer Calibration

The solar paddles were propped up by wooden supports near the tips except when torquemeter measurements were taken. At this time, the props were removed and the solar paddles were guyed back to the spacecraft body for support.

Magnetic measurements were made during the initial series of tests. These measurements were made at four different positions north of the center of the coil system using Forster-Hoover Model MF 5050 tri-axial probes. The signals from the probes were hard-wired to the Operations and Instrumentation Building where they were displayed as meter indications, as analog traces on recorders, and as digital printouts (MADAS). The meter readings and analog traces were used for real time quick look monitoring while the MADAS record was entered into a digital computer near field analysis program for the calculation of dipole moment components. A summary of the principal findings appears in Table I.

Procedure

Initial magnetic tests were performed on SAS-A during July 1970. These consisted of:

1. "As received" magnetic moment measurement
2. Permanent magnet compensation
3. Trim magnet dipole moment measurement
4. Residual magnetization due to operation of spin and attitude coils
5. Attitude coil magnetic moment measurement
6. Measurement of on-board demagnetizer effectiveness
7. Stray field magnetic moment measurement
8. Measurement of induced dipoles
9. Alignment, calibration and bias measurement of on-board magnetometers
10. Spin-despin system torque measurements

Final magnetic tests were performed in October 1970. These consisted of:

"As received" permanent magnetic moment measurement

Table I

Partial Summary of Results

Quantity	Spacecraft State	Initial Dipole Moment Milliampere-Meter^2			Final Dipole Moment Milliampere-Meter^2			Nominal Dipole Moment Milliampere-Meter^2		
		M_x	M_y	M_z	M_x	M_y	M_z	M_x	M_y	M_z
Perm Moment	"As Rec'd"	-258	-47	+244	—	—	—			
Perm Moment	Post Comp.	+59	-47	-49	+12	0	0	±10	±10	±10
Z Coil Moment	+High Gain			$+4.9 \times 10^4$			$+4.5 \times 10^4$			$+5.0 \times 10^4$
	-High Gain			-4.75×10^4			—			-5.0×10^4
	-Low Gain			-0.415×10^4			—			-1.0×10^4
	+Low Gain			$+0.464 \times 10^4$			0			$+1.0 \times 10^4$
Trim Magnet Moment Range		388	384	1783				400	400	1600
Damper Solen-oid Moment		- 365 -						Approx. 300		
Moment Due To Stray Fields	Recorder In Playback				Change of Approximately 200 on X Axis					
Spin Control System Torques	Exposed to 35,000 N-T Rotating Field	Initial Torque in Newton Meters x 10^7 by Torquemeter			Final Torque in Newton Meters x 10^7 by Analog Computer			Nominal Torque in Newton Meters x 10^7		
	+Command	+3240			+3600			+3500		
	-Command	-3540			-3550			-3500		

Recompensation of permanent magnetic moment

Stray field magnetic moment measurement

Attitude coil magnetic moment measurement

Alignment check, calibration and bias measurement of on-board magnetometers

Calculation of spin-despin system torques by analog computer

The details of the procedures followed in carrying out these tests and the computational techniques used are summarized in Appendix B.

INITIAL TEST

Results and Discussion

The magnetic moment components of the spacecraft in its "as received" state as measured by near field analysis were:

$$M_x = (-260 \pm 10) \text{ milliampere meters squared}$$

$$M_y = (\ -45 \pm 15) \text{ milliampere meters squared}$$

$$M_z = (+255 \pm 10) \text{ milliampere meters squared}$$

A large number of dipole moment measurements was made using the Mark VI Torquemeter. These measurements appear in Table II. During these tests the spacecraft was oriented such that its +Z axis pointed north. The X and Y moment components were measured by re-orienting about the Z axis, using the roll ring adapter provided by APL.

Examination of Table II yields the following comment: The "as received" dipole moment components as calculated from the near field magnetometer data are in excellent agreement with those obtained by use of the Mark VI Torquemeter.

Compensation with Alnico magnets reduced the perm moment components substantially. While the moments were in excess of the 10 milliampere meters squared goal, they were within the range of adjustment of the chargeable trim magnets.

Table II

Magnetic Moments - Initial Tests

Test Objective	Spacecraft State	Magnetic Moment In Milliampere-Meters^2		
		M_x	M_y	M_z
"As Received" Moment	Transmitter on Systems Caged	-258	-47	+244
Moment Due to Caging System	Nutation Damper and Moment Wheel Uncaged	-258	-82	+244
	Change due to Caging	0	-35	0
Z Coil Moments	+Z High Gain			4.9×10^4
	-Z High Gain			-4.75×10^4
	-Z Low Gain			-0.415×10^4
	+Z Low Gain			$+0.464 \times 10^4$
X Trim Magnet System Calibration	Nominal Zero	+70		
	Full Negative	-94		
	Full Positive	+294		
	Range	388		
Y Trim Magnet System Calibration	Nominal Zero		-188	
	Full Negative		-384	
	Full Positive		0	
	Range		384	
Z Trim Magnet System Calibration	Nominal Zero			+235
	Full Negative			-646
	Full Positive			+1137
	Range			1783

Table II (continued)

Test Objective	Spacecraft State	Magnetic Moment In Milliampere-Meters^2		
		M_X	M_Y	M_Z
Nutation Damper Solenoid Dipole Moment	Solenoid EW			
	Solenoid Off		212E	
	Solenoid On		153W	
	Solenoid Moment		365W	
Nutation Damper Magnet Moment	Minimum State	+70	-211	+215
	Maximum State	-188	-518	+274
Residual Moment Z Coil Operation with Nutation Damper in Minimum State. Also Demag Effectiveness	+Z High-On-Off			+254
	-Z High-On-Off			+206
	Demag			+225
	+Z High-On-Off			+254
	Demag			+244
Stray Field Measurement Range of Moments	Power Input Point - X Solar Array	-224	-24 to -128	+216 to +225
	Damper Solenoid On w/+Y West		-247	
	+X Solar Array	-224	-94 to -106	+216
	-Y Solar Array	-224	-106	+216
	+Y Solar Array	-223 to -234	-94	+216
	Damper Solenoid On w/+X West	+106		
Post Compensation Dipole Moment		+59	-47	-49

The Z coil dipole moment was adequate in the high gain mode, but was only about half strength in the low gain mode. It was later discovered that the problem was a loose terminal connection. This was reported to have been corrected subsequent to the initial test.

Residual moments due to Z coil operation were found to be minor and were corrected by operation of the on-board demagnetizer. The X and Y coil residuals were not checked.

Extraneous dipoles due to stray currents were negligible except when the damper solenoid was energized.

The technique used to measure induced dipole moments was unsuccessful in that a satisfactory null could not be achieved. The measurement attempt must be regarded as an experiment, no proven torquemeter technique being available at this time.

The magnetometer alignment, calibration and bias investigation was carried out with the results given in Tables III and IV, and the curves shown in Figures 3, 4, and 5.

As may be seen from Table III, the misalignment was a maximum of

$$\frac{0.021}{8.28} = \frac{1}{394} \text{ required limit was 1 part in 300 or better}$$

All operating modes introduced a negligible bias at the magnetometer sensors, except for the "wheel off" and "Z coil on" modes. The results for these appear in Table IV.

The results of the spin-despin system tests are presented in Table V.

The presence of the solar paddles augmented the noise level during these tests. The noise level was large at the start and decreased as the test progressed. As testing time was limited, data had to be taken before the noise had subsided to a minimum. Nevertheless, the torques confirmed the design values in both magnitude and direction.

Table III

Magnetometer Alignment Test Results

Field (Nanoteslas)			Magnetometer Output - Volts		
H_x	H_y	H_z	V_x	V_y	V_z
0	0	0	-0.048	+0.028	+0.012
+35 K	0	0	+4.133	+0.028	+0.005
-35 K	0	0	-4.288	+0.028	+0.019
0	0	0	-0.048	+0.028	+0.012
0	+35 K	0	-0.046	+4.212	+0.022
0	-35 K	0	-0.049	-4.152	+0.001
0	0	0	-0.048	+0.028	+0.012
0	0	+35 K	-0.042	+0.017	+4.164
0	0	-35 K	-0.053	+0.038	-4.141
0	0	0	-0.048	+0.028	+0.013

FINAL TEST

Results and Discussion

After recompensation with permanent magnets, the permanent magnetic dipole moment components of the spacecraft were as follows:

$$M_x = 12 \text{ Milliampere meters squared}$$

$$M_y = 0$$

$$M_z = 0$$

Table IV

Magnetometer Bias Measurements

State	Field Magnetometer Outputs					
	H_x	H_y	H_z	V_x	V_y	V_z
Wheel On	0	0	0	-0.048	+0.028	+0.011
Wheel Off (Nutation Damper Solenoid On)	0	0	0	-0.044	+0.026	+0.119
Z Coil Off	0	0	0	-0.047	+0.028	+0.009
Z Coil On:						
High Positive	0	0	0	-0.724	+0.658	+6.833
Low Positive	0	0	0	-0.180	-0.105	+1.336
High Negative	0	0	0	+0.628	+0.714	-6.823
Low Negative	0	0	0	+0.028	+0.162	-1.335

These measurements were made with the X and Y trim magnets in their nominal zero state. The Z trim magnet had a small bias. However, it was found that the residual perm moments of the spacecraft had changed significantly since the initial series of tests. It was noted that a large number of changes had been made in the interim, including replacement of the tape recorder, blade hinges, coax cables, and remounting of trim magnets.

Turn on of various sub-systems produced negligible variations in moment, except for the tape recorder in the play back mode. This produced a moment along the X axis too large to be nulled out.

The attitude coil moments were measured with the following results:

Orientation	Mode	Measured Moment*	Nominal Moment*
+Y Up	Hi Gain	42,000	50,000
+Y Up	Lo Gain	0	10,000
-X Up	Hi Gain	47,000	50,000
-X Up	Lo Gain	5,600	10,000

*In Milliampere Meters, Squared

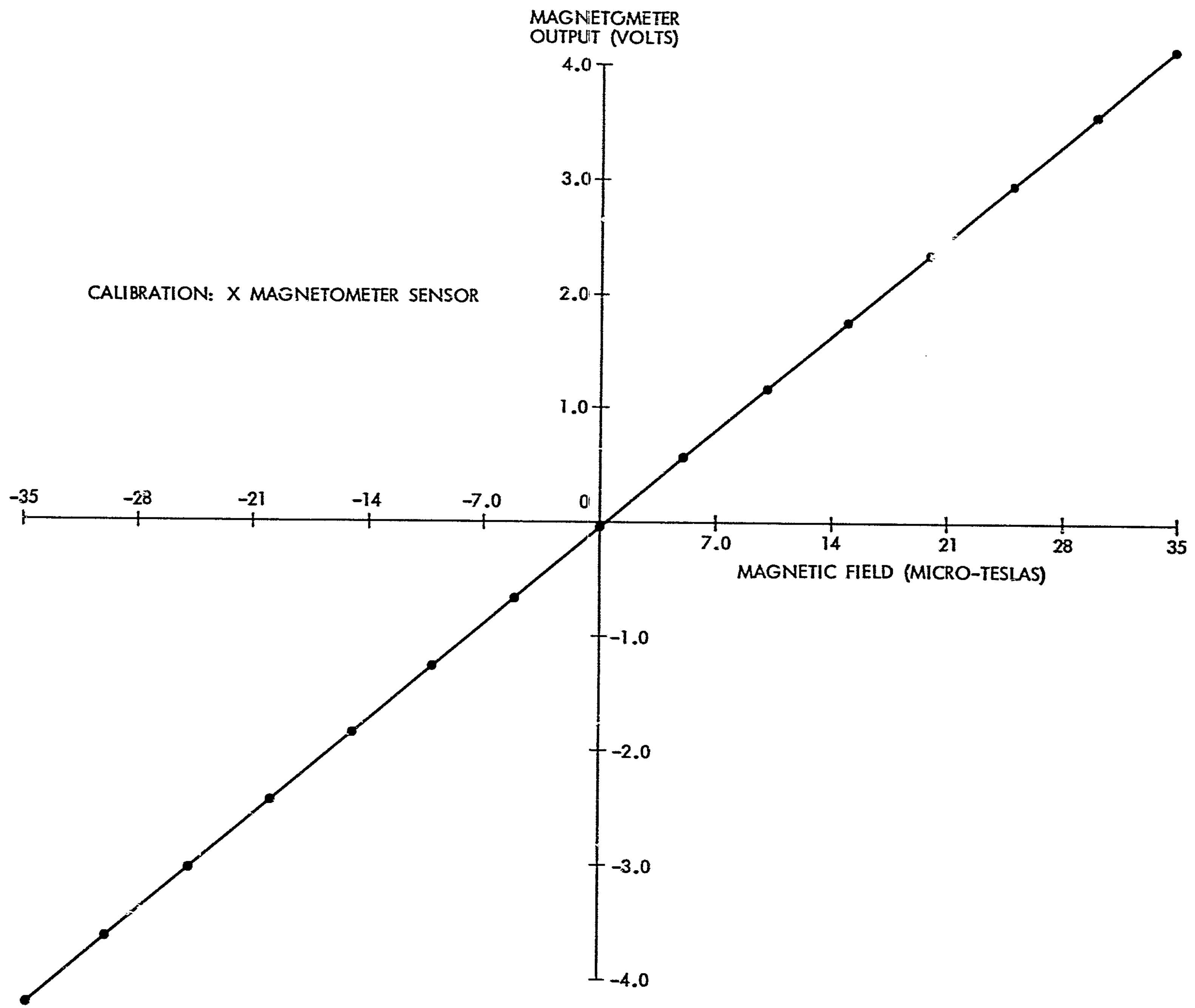

Figure 3. Calibration Curve for X Magnetometer Sensor

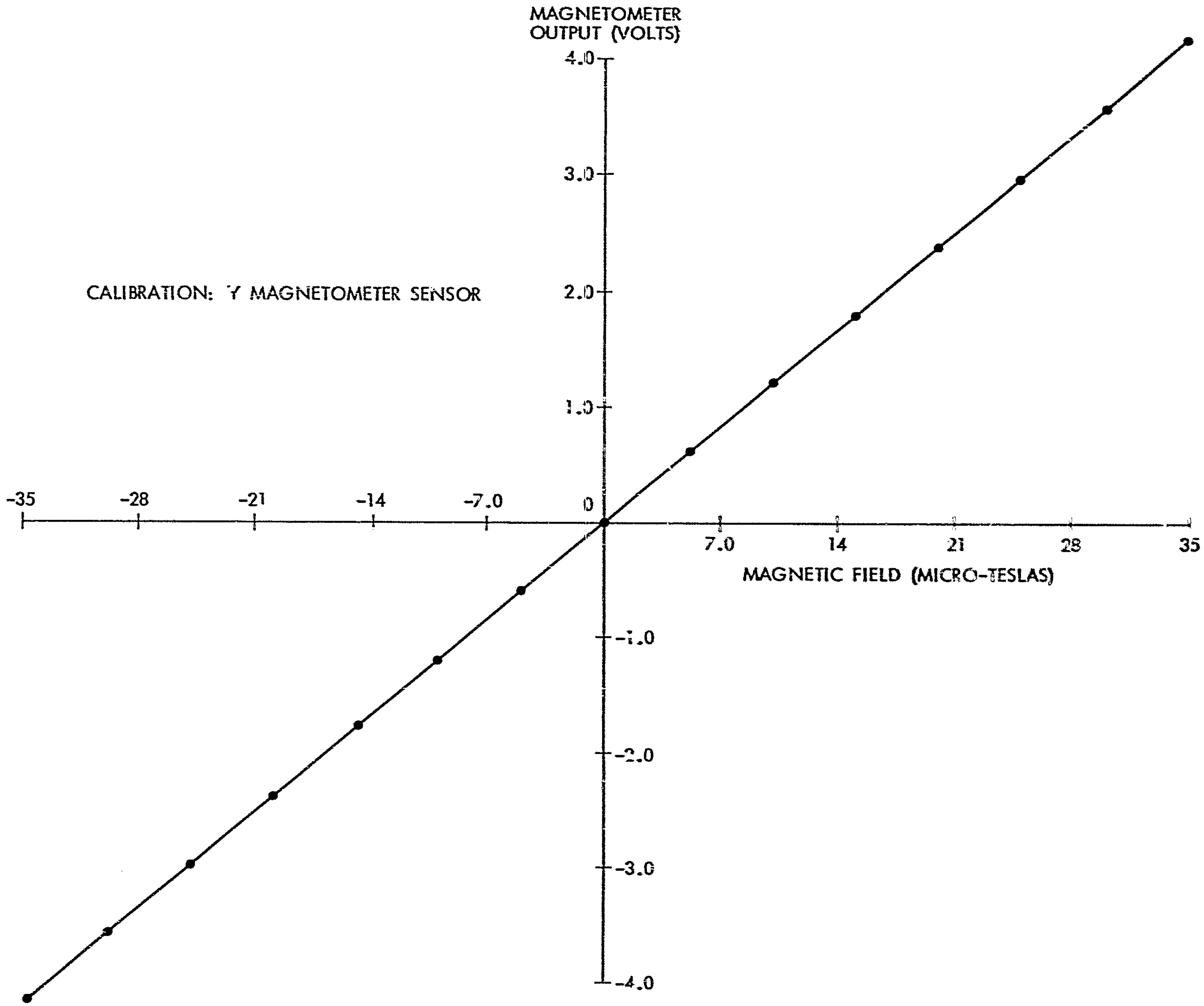

Figure 4. Calibration Curve for Y Magnetometer Sensor

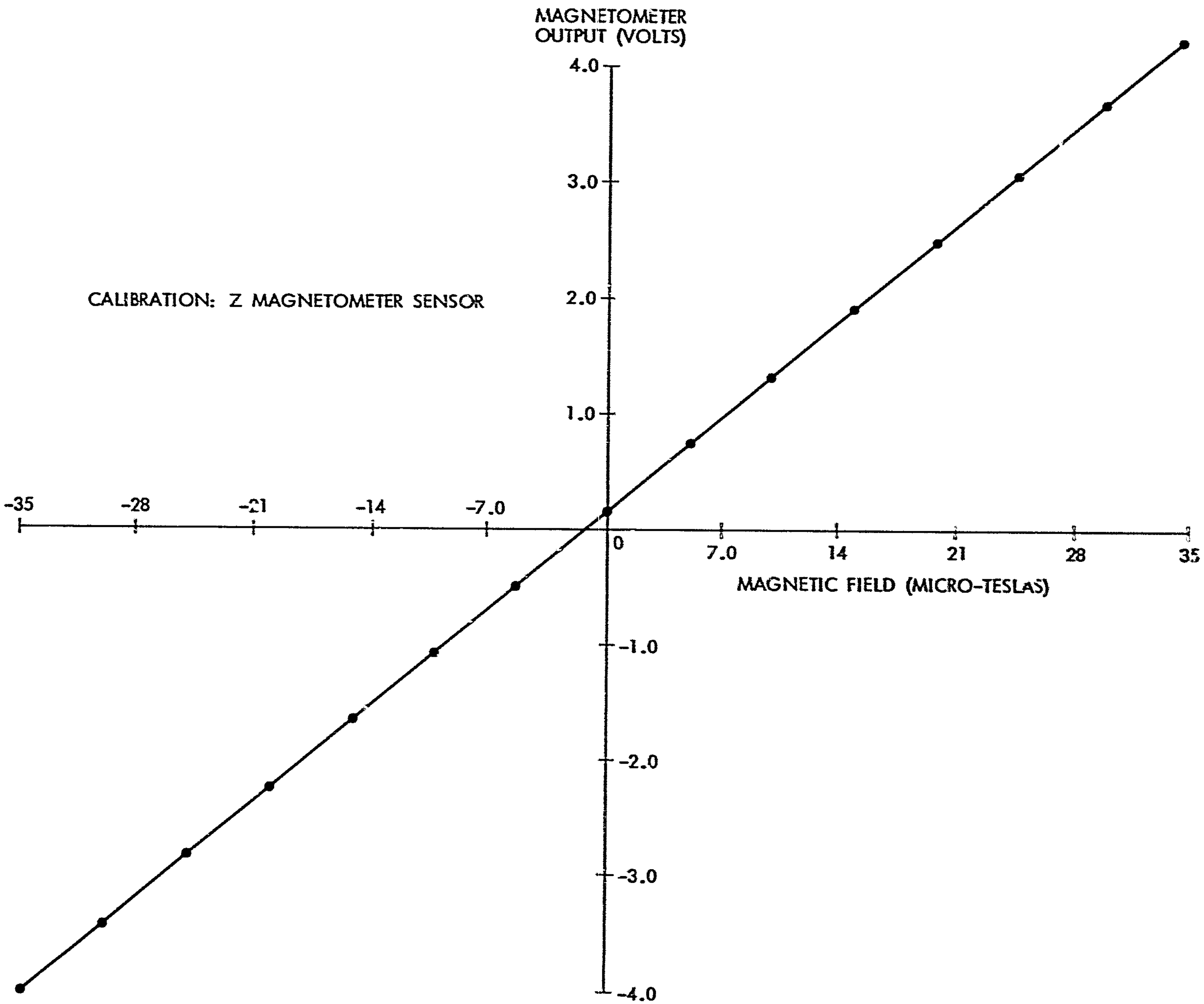

Figure 5. Calibration Curve for Z Magnetometer Sensor

Table V

Spin Control System Test Results

Magnetic Field (Nanoteslas)	Averaged Torque Values (Newton-Meters x 10^7)	Expected Torque Values (Newton-Meters x 10^7)	Comments
35,000 -X Direction	3520	3500	
35,000 +Y Direction	3420	3500	
20,000 +Y Direction	1190	1142	
20,000 +X Direction	1280	1142	
35,000 C-C1 Rotation X-Y Plane, 3 RPM	2610	3500	
35,000 C-C1 Rotation X-Y Plane, 1 RPM	2250	3500	Large error due to attitude control system pwr supply limiting. Battery power was used in all the following tests.
35,000 C-C1 Rotation X-Y Plane, 10 RPM	3060	3500	
As Above, Except C1 Rotation	3260	3500	Large error due to off scale deflections on recorder.
Above Fld + Static 30,000 +Z Dir.	3570	3500	
Above Fld + Static 30,000 -Z Dir.	3390	3500	
20,000 C1 Rot. X-Y Plane, 10 RPM	1260	1142	
20,000 C-C1 Rotation Plane, 10 RPM	1260	1142	

Subsequent to the magnetic test it was found that the Z coil insulation had been worn through by a cable clamp which it contacted. This condition was reported to have been corrected subsequent to the final magnetic test.

Proper alignment of the magnetometer sensors was reconfirmed. The slopes of the calibration curves were found to be the same as in the initial test but the probe biases were significantly changed (about 3% of full scale). This was acceptable. Bias effects due to operation of the Z coil were measured so that proper operation of the coil could be confirmed in orbit.

The spin control system torques were calculated by analog computer, using as inputs, signals proportional to the components of the rotating field and signals proportional to the currents in the X and Y spacecraft coils. The analog computer was programmed to calculate the spin axis torque and display it as a function of time on an X-Y recorder.

Computations were made over a range of rotating field frequencies from the lowest possible (approximately 0.3 rad/s) to 1.04 rad/s. The field amplitude was varied over the range of 10,000 to 35,000 nanoteslas.

The torques were of the anticipated magnitude at the lower frequencies but read about 15% high at the maximum frequency. This appeared to be due to a frequency sensitivity within the analogue computer. As an example of typical data, the results calculated for 0.0523 rad/s (0.5 RPM) are as follows:

Frequency	Field N-T	Command Sense	Calculated Torque N-M	Nominal Torque N-M
0.5 RPM	10,000	+ Spin	[illegible]00 x 10^{-7}	+286 x 10^{-7}
0.5 RPM	20,000	+ Spin	+1200 x 10^{-7}	+1142 x 10^{-7}
0.5 RPM	35,000	+ Spin	+3600 x 10^{-7}	+3500 x 10^{-7}
0.5 RPM	10,000	- Spin	-300 x 10^{-7}	-286 x 10^{-7}
0.5 RPM	35,000	- Spin	-3550 x 10^{-7}	-3500 x 10^{-7}

Problems

The principal difficulty encountered in both initial and final testing was the improper performance of the Z coil. In the initial test, a loose connector prevented proper operation and in the final test, proper results could not be gotten because of a grounding problem occasioned by insulation abrasion.

Measurements of spin coil torques made during the initial tests were difficult to obtain accurately due to a large noise component. This large noise level was due to the presence of the solar paddles which magnified the effect of stray air currents within the enclosure. It was noted that the noise level was slowly decreasing but lack of time did not permit waiting for the noise to reach a minimum before taking of data.

During the analog computer test, it was noted that the two components of the rotating field were of unequal amplitude, the north-south component being about 10% higher than the east-west component. Adjustments were made to the control settings to equalize the components and the analog computations were then made.

The on-board tape recorder was replaced between the initial and final tests. The new recorder produced a large moment in the play back mode (approximately 200 milliampere meters^2) along the X axis.

During the initial testing of the spin-despin system it was found that the external power supply for the spin control system was limiting the coil current. Spacecraft battery power was then used which corrected the problem.

Attempts to measure the induced moments of the spacecraft were unsuccessful. This points up the fact that we do not have a good technique for measuring the induced dipoles by means of the torquemeter at this time.

CONCLUSIONS

After re-compensation with permanent magnets, the final permanent moment of the spacecraft was 12 milliampere meters squared with the trim magnets close to their nominal zero state. The trim magnets are capable of nulling out biases of up to ±190 milliampere meters squared along the X and Y axis and ±890 milliampere meters squared along the Z axis. This is ample to negate spurious dipoles due to operation of on-board equipment, except for the tape recorder in the play back mode. This might require corrective action from the attitude coil, although the play back mode is understood to be only on for a few minutes at a time.

The spin-despin system performance was satisfactory.

The attitude control system did not perform satisfactorily during either test due to loose terminal connectors and insulation abrasion. Both these conditions have been reported to have been corrected.

The on-board demagnetizing system performed satisfactorily.

Alignment, bias measurement and calibration of the flight magnetometer were satisfactorily performed.

Attempts to measure induced dipoles were inconclusive.

ACKNOWLEDGEMENT

Much of the data presented in this report was gathered by personnel of the Applied Physics Laboratory, who were kind enough to make it available. The acquiring of the data was accomplished as a team effort by personnel of the Magnetic Test Section, GSFC, and by personnel of APL. In general, data external to the spacecraft, such as the torque and near field measurements were acquired by the Magnetic Test Section while data internal to the spacecraft, such as magnetometer calibration and analogue torque computation were by APL.

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APPENDIX A

DESCRIPTION OF FACILITY

The Spacecraft Magnetic Test Facility (SMTF) shown in Figure A-1 provides a controlled magnetic environment in which to carry out magnetic tests of spacecraft or spacecraft components. The 12.8 meter (42 foot) diameter, 3 axis coil system permits the establishment of zero field or a field of any desired magnitude and direction with a maximum of 60,000 nanoteslas per component. Current regulated power supplies provide stability of ±1 nanotesla over a 24 hour period while the coil geometry provides uniformity of field within 0.6 nanoteslas over a spherical volume of 0.98 meters (3.2 foot) radius. Three earth's field magnetometers and associated control systems provide automatic compensation for the daily variation of earth's field.

In addition to the generation of static magnetic fields, the coil current may be programmed so as to produce a resultant vector which will rotate about any desired axis through the center of the coil system at a maximum rate of 100 radians per second. The magnitude of the rotating vector has a maximum limit of 60,000 nanoteslas.

The facility is also equipped with a 22,240 newtons (5000 pound) capacity overhead hoist, a 8896 newton (2000 pound) capacity hydroset for gentle handling of delicate spacecraft, a track system and dolly for transporting the spacecraft from the trucklock to the center of the coil system and a turntable at the coil center which is powered to rotate the spacecraft through 360 degrees while it is centered in the coil. The turntable is equipped with an angle encoder so that angular position and magnetic measurements may be synchronized. In addition, a gimbal is available with which to produce rotation of the spacecraft about a horizontal axis. Fields up to 50×10^{-4} teslas for perming and deperming the spacecraft along one axis can be provided by means of a portable helmholtz coil pair of 2.74 meters (9 foot) diameter. There is also available a 1.52 meter (5 foot) diameter coil for applying such fields along a second axis of the smaller spacecraft.

The facility is equipped with a highly sensitive torquemeter located directly below the turntable, which permits the direct measurement of torques resulting from the interaction between the magnetic moment of the spacecraft under test and the field produced by the coil system itself. The torquemeter can be rigged to accept loads to 22,240 newtons (5000 pounds) and to measure torques to an accuracy of 50×10^{-7} newton meters (50 dyne centimeters). An additional torquemeter is also available for use with spacecraft weighing up to 3781 newtons (850 pounds). With this instrument, small torques have been measured to an accuracy of 10^{-6} newton meters (10 dyne centimeter).

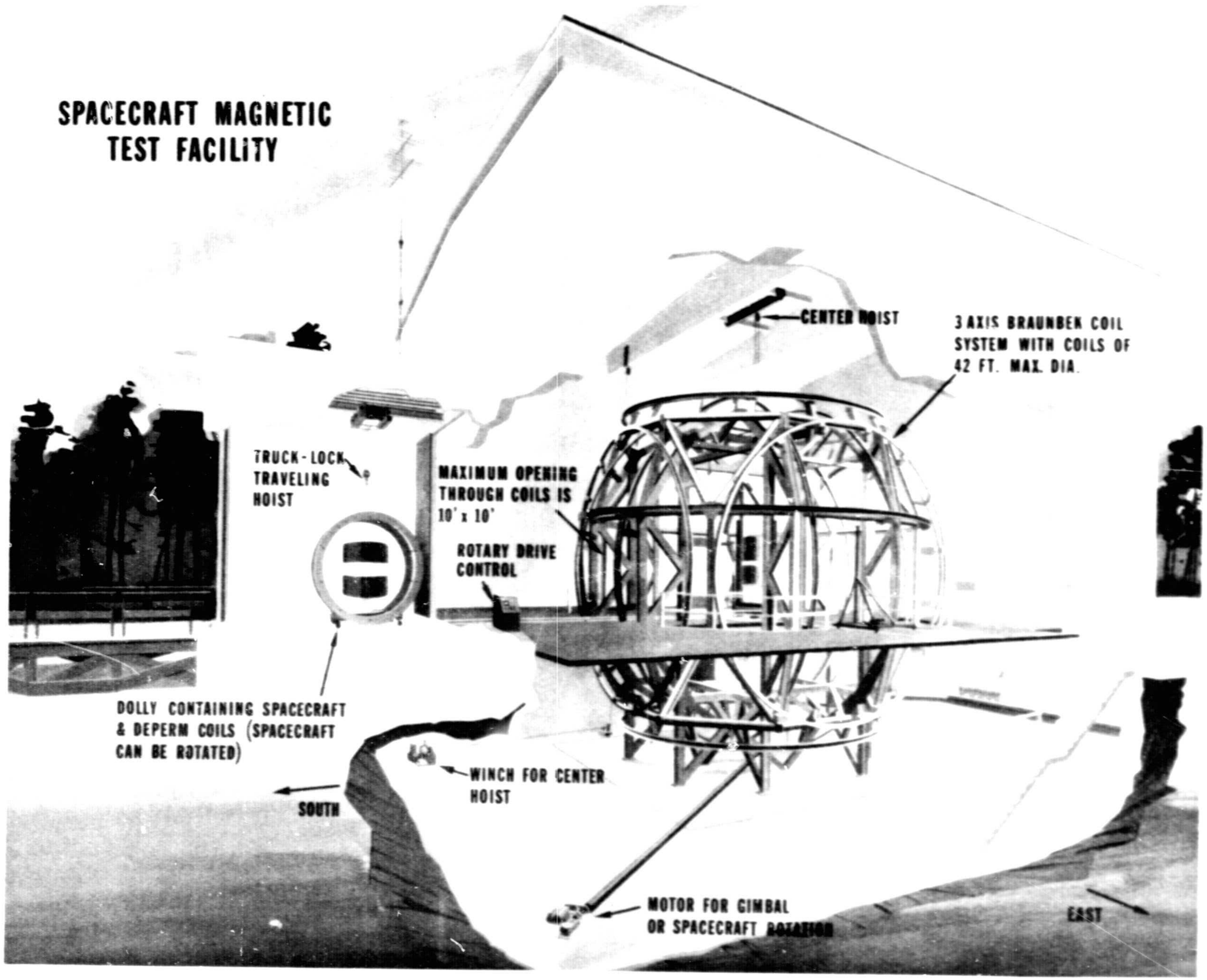

Figure A-1. Spacecraft Magnetic Test Facility

Four tri-axial fluxgate type magnetometers are available and may be used simultaneously to provide meter display, strip chart records or digital print-out records. The positions of the magnetometer probes may be varied to suit the particular needs of the individual spacecraft or sub-system under test.

A photograph of the SAS-A spacecraft under test in the facility is shown in Figure A-2.

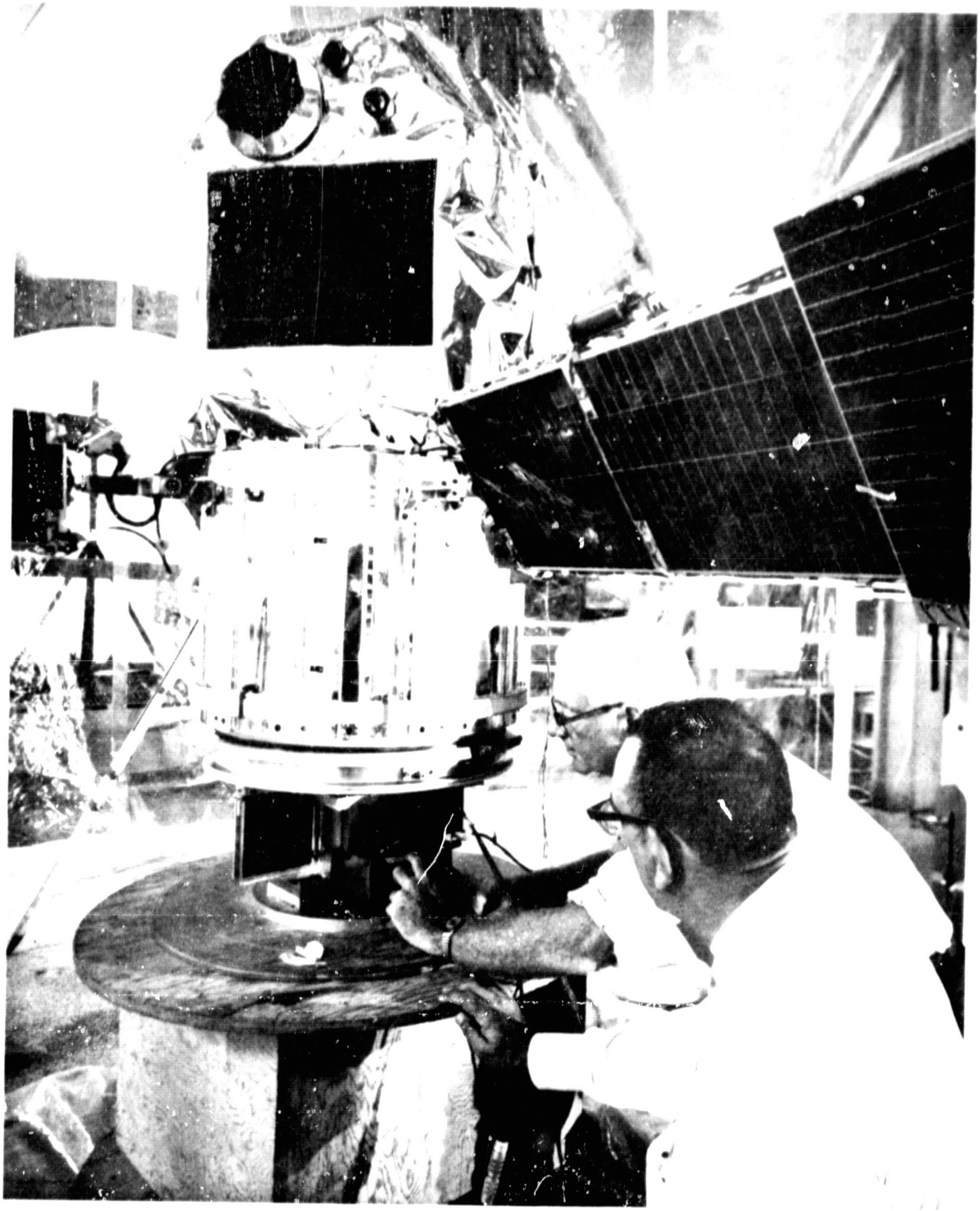

Figure A-2. SAS-A Spacecraft in the Spacecraft Magnetic Test Facility

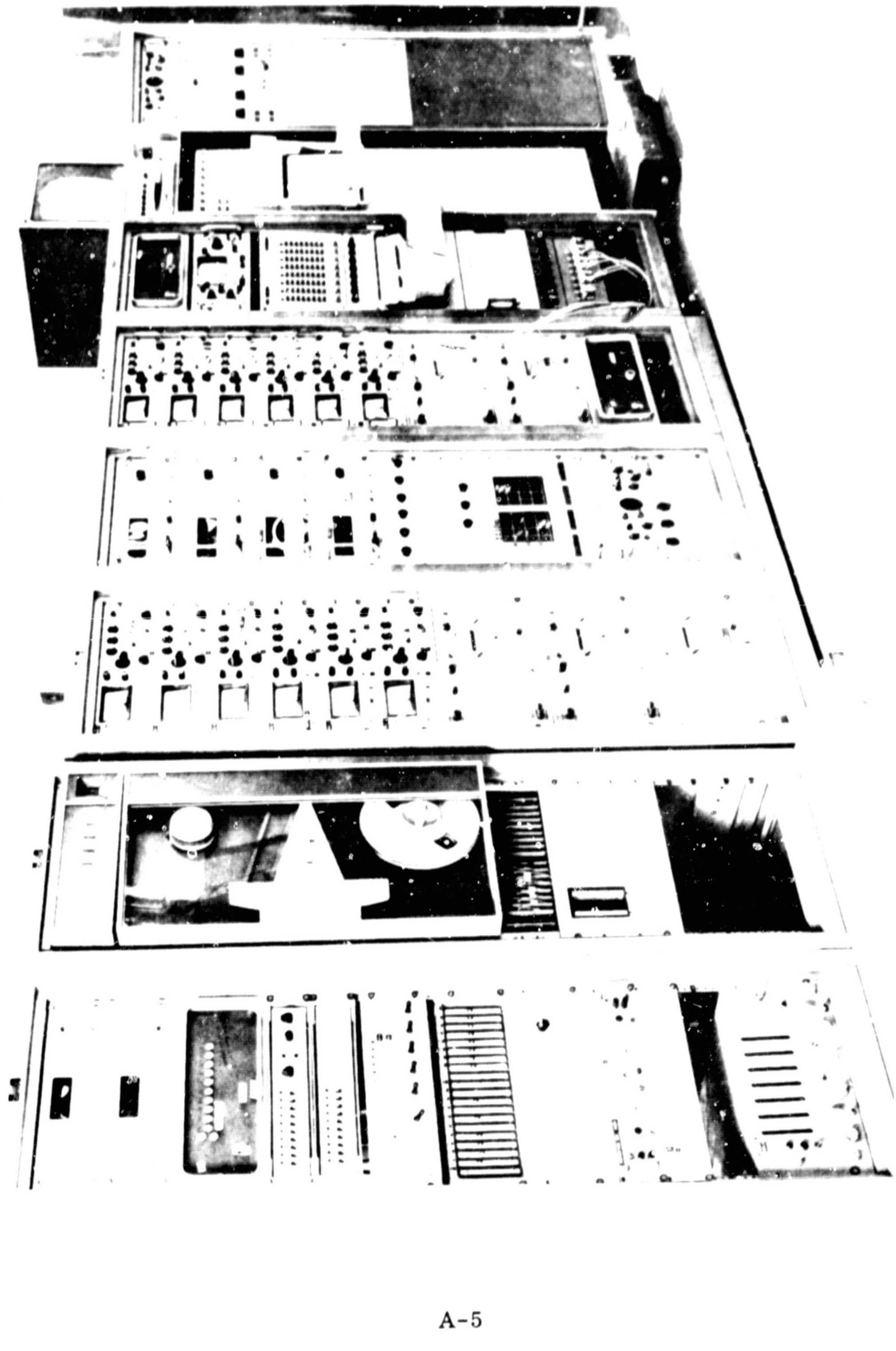

Figure A-3. Recording Instrumentation for Magnetic Tests

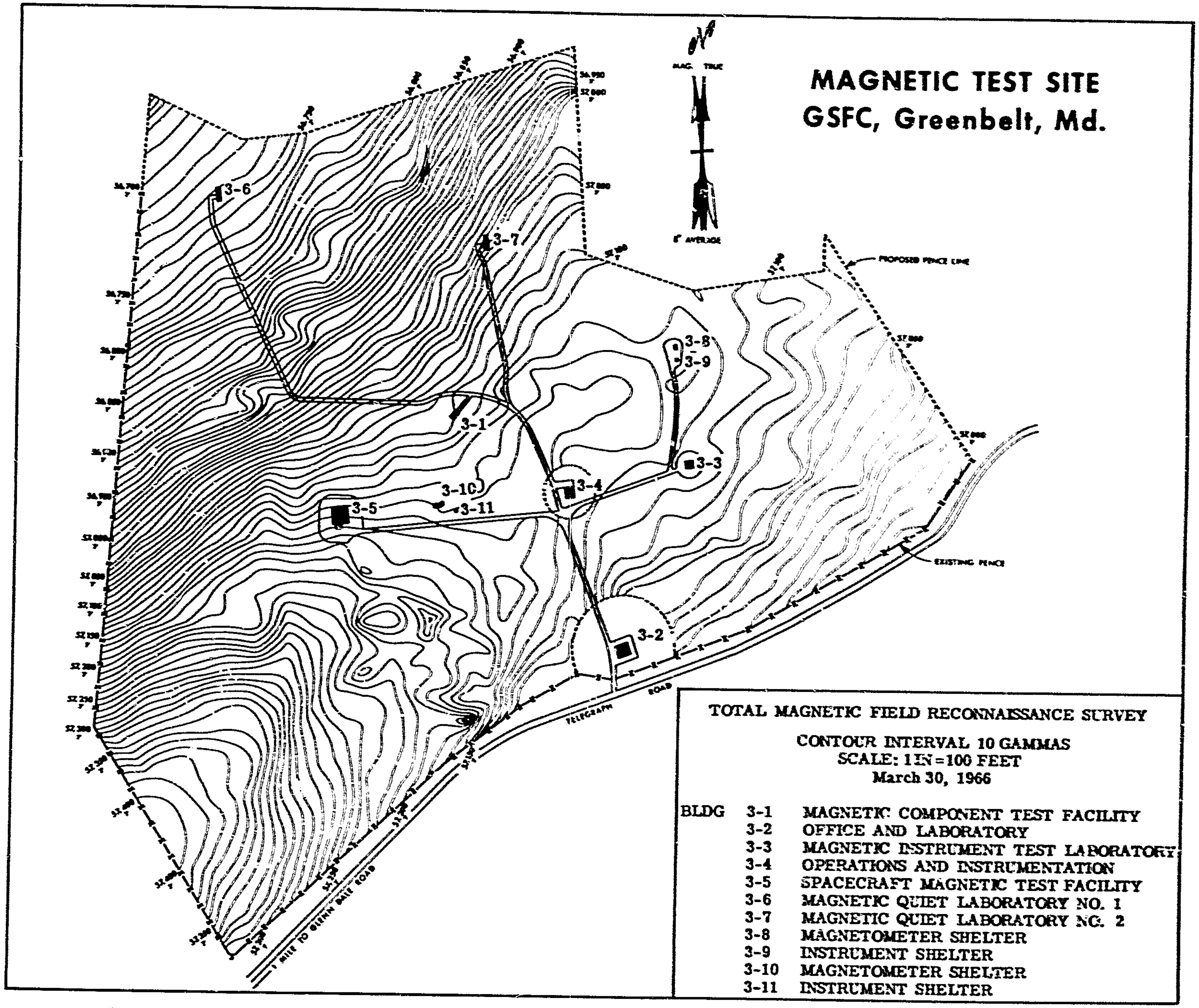

Figure A-4. Total Magnetic Field Reconaissance Survey of Magnetic Test Site

APPENDIX B

TEST PROCEDURES AND COMPUTATIONAL TECHNIQUES

DIPOLE MOMENT DETERMINATION

A. Near Field Analysis

The location of the magnetometer probes relative to the spacecraft is shown in Figure B-1. The probes were Forster Hoover Model MF 5050 triaxial fluxgates whose outputs were hard wired to the Operations and Instrumentation Building where they were recorded both on strip charts and in digitized form on magnetic tape (MADAS system).

The magnetic signatures of the spacecraft were found to be quite non-dipolar, indicating the presence of higher order multipole components. To extract the dipole components, a near field analysis technique has been developed. The mathematics of this technique are highly complex and will not be described here.

Reference 10 describes the process. The results are tabulated in Table B-I.

Table B-I

Calculated Dipole Moments of the SAS-A Spacecraft in Milliampere-Meters^2 - From Near Field Analysis	
M_x =	-260 ±10
M_y =	-45 ±15
M_z =	+255 ±10

B. Torquemeter Measurement

In determining magnetic dipole moments by torque measurements, the spacecraft was mounted horizontally with its +Z axis pointing north. A special ring fixture permitted the spacecraft to be rotated about the Z axis so as to place either the X or Y axis horizontal. The ring fixture was in turn mounted on the Mark VI Torquemeter.

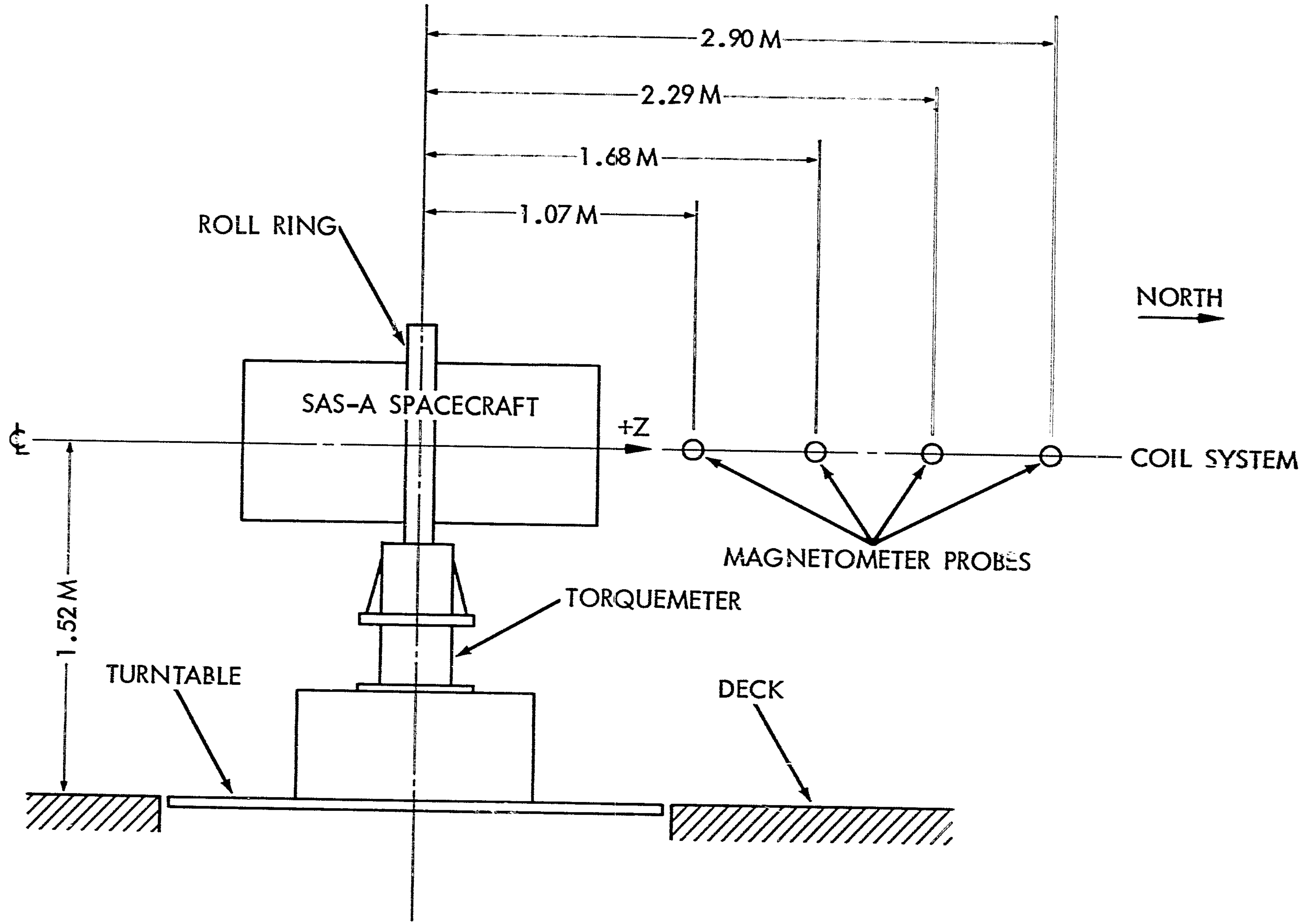

Figure B-1. SAS-A Test Configuration for Near Field Measurements

The test procedure consisted of applying an oscillating facility field so as to produce a corresponding oscillating torque due to the dipole moment component at right angles to the field. For example, if an oscillating east-west field were applied, the torque observed would be due to the moment in the north-south (Z) direction. If now the north-south torquemeter coil were energized so that its moment exactly cancelled the spacecraft moment, the torque output would be reduced to zero, or nearly so. The moment is equal to the product of the coil constant and the current both of which are known. The sense of the spacecraft moment is opposite to that of the torquemeter coil. In like manner, we may apply an oscillating north-south field and, using the east-west torquemeter coil, null out the X or Y spacecraft moment component depending on which one is in the horizontal plane at the time.

When these measurements are being made, the torquemeter filter is set to band pass a narrow range centered on the oscillating field frequency. This aids in detecting the null by eliminating DC drift and most of the noise.

C. Far Field Measurement

Although it was evident by inspection of the field signatures that there was considerable non-dipolar component present, a far field analysis was performed as a matter of interest using the data collected at the probe located 7 feet away.

The results of all three techniques are compared in Table B-II.

Table B-II

"As Received" Dipole Moment Components
in Amp $M^2 \times 10^3$

Torquemeter		Near Field	Far Field
M_x	-258	-260	-222
M_y	-47	-45	-153
M_z	+244	+255	+185

It is evident that the torquemeter and near field analysis yielded results that were in very good agreement, but the far field results contained large discrepancies.

MAGNETOMETER ALIGNMENT
BIAS DETERMINATION AND CALIBRATION

For these measurements the Z axis was oriented vertically on the torquemeter. It was then leveled to +0.63 cm in 9 meters and oriented with the +Y axis directed north. The solar paddles were attached and supported from the floor by wooden props. The torquemeter was merely acting as a support and was pinned securely against rotation. In this orientation there was a 15 degree angular displacement between the torquemeter coil axes and the facility coil system axes.

To effect proper magnetometer sensor alignment a magnetic field of 35,000 nanoteslas was applied perpendicular to the axis of each magnetometer sensor. The orientation of each sensor was then adjusted for minimum output voltage. Alignment requirement was 1 part in 300.

After magnet compensation of the magnetometer sensors, different spacecraft and experiment operating modes were exercised while the spacecraft magnetometer outputs were monitored for bias effect.

The magnetometer sensors were calibrated by applying a magnetic induction ranging from +35,000 to -35,000 nanoteslas in 500 nanoteslas steps, then repeating from -35,000 to +35,000 nanoteslas. Data were obtained both by hardwire from the spacecraft and by telemetry. Proper vector behavior was confirmed by rechecking selected calibration points while an orthogonal field of 30,000 nanoteslas was applied.

The in-flight calibration system was exercised and calibrated by command at applied field levels ranging through ±35,000 nanoteslas.

SPIN CONTROL SYSTEM EVALUATION

A. Torquemeter

During these tests the spacecraft was mounted on the torquemeter with +Z axis up. The solar paddles were in place but were guyed back to the satellite.

The test procedure consisted of applying a magnetic field, rotating about a vertical axis and commanding the spin-despin system on and off in both the positive and negative sense. The resulting magnetic interaction torque was simultaneously measured. This was done at several field levels up to 35,000 nanoteslas and at field rotational rates varying from the lowest possible 0.0314 rad/s (0.3 RPM) to 1.04 rad/s (10 RPM). In addition, tests were made with a static Z field applied simultaneously with the rotating field to check for possible interactions.

B. Analog Computer

In this test the spacecraft was mounted on the torquemeter with its +Z axis up and with two solar paddles in position. The torquemeter merely acted as a support and was inoperative.

Signals proportional to the X and Y spin coil currents along with signals proportional to the X and Y applied fields were fed as inputs to a PACE TR-10 Analog computer. The computer was programmed to solve the equation

$$L = M_x H_y - M_y H_x$$

where

L = Spin Axis Torque

M_x = Dipole Moment of X coil

M_y = Dipole Moment of Y coil

H_x = Applied Field in X direction

H_y = Applied Field in Y direction

The output torque signal was fed to an X-Y recorder on which it was displayed as a function of time.

APPENDIX C

CHRONOLOGY OF EVENTS

INITIAL TESTS

<u>Thursday, July 23, 1970</u>

SAS-A spacecraft arrived at the Magnetic Test Facility (PM)

<u>Friday, July 24, 1970</u>

Set spacecraft in nominal zero state.
Measured initial perm by near field technique.

<u>Monday, July 27, 1970</u>

Measured initial perm by torque measurement
Began stray moment measurements by torquemeter

<u>Tuesday, July 28, 1970</u>

Continued stray moment measurements
Checked demagnetizer effectiveness
Calibrated X, Y and Z trim magnets
Attempted measurement of induced dipole moments

<u>Wednesday, July 29, 1970</u>

Completed stray moment measurements
Initiated spacecraft compensation with permanent magnets

<u>Thursday, July 30, 1970</u>

Completed spacecraft compensation
Initiated alignment calibration and bias check of flight magnetometer

<u>Friday, July 31, 1970</u>

Completed alignment calibration and bias check of flight magnetometer
Evaluated spin-despin torquing system
Spacecraft left Magnetic Test Site at 7:00 PM

FINAL TESTS

Thursday, October 22, 1970

SAS-A spacecraft arrived at Magnetic Test Site in PM

Friday, October 23, 1970

Set spacecraft in nominal zero state
Recompensated spacecraft with permanent magnets
Measured stray moments by torquemeter
Measured Z coil moments by torquemeter

Saturday, October 24, 1970

Checked alignment, calibration and biases on the flight magnetometer
Checked operation of spin control system with analog computer
Spacecraft left Magnetic Test Site 4:00 PM

NASA—GSFC COML., Arlington, Va.